HOME MADE APPARATUS

JOHN F. WOODHULL

MANUAL

OF

HOME-MADE APPARATUS

WITH REFERENCE TO

CHEMISTRY, PHYSICS, AND PHYSIOLOGY.

BY

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HOME-MADE APPARATUS.

PART I. COURSE IN GLASS-WORKING.

1. **Bending Glass Tubing.**—Small glass tubing may be bent in an ordinary gas or kerosene-lamp flame, but an alcohol lamp or Bunsen burner is preferred. The glass should be well softened, by heating it in the flame, before attempting to bend it. If, for example, the end *a* (figure 1) is one and one-half inches from the flame, the tube ought to be softened enough so that it will bend down of its own weight.

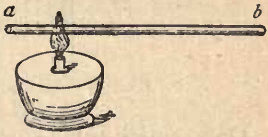


FIG. 1.

At first keep the tube constantly rolling, so as to heat it on all sides, but when it begins to bend cease rolling, and move it a little to the right and left, to heat the adjacent parts. *Do not let it bend rapidly.* By moving it to the right and left occasionally you may keep it bending slowly in as gradual a curve as you may desire. Figure 2 represents a tube bent thus. It is well to remember that the hot part of the flame is at the outer edges, where the combustible vapors come in contact with the air. A tube, therefore, if kept perfectly still in a flame, would be liable to bend as represented in figure 3, because it would be softened chiefly at the points *c* and *d*. In this matter perfection can be reached only by much practice. Patience rather than skill is the requisite capital. Hence there is no reason why any one may not bend glass tubing sufficiently well for all practical purposes.

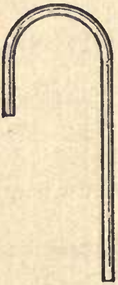


FIG. 2.

FIG. 3.

Only small tubing, whose inside diameter does not exceed three-sixteenths of an inch, can be readily bent in an alcohol flame; and for this purpose the wick must be drawn up half or three-quarters of an inch and the tube must be held in the hottest part of the flame, which is the upper third. Glass tubing is quite inexpensive. It should not cost over fifty cents a pound, and a pound of the size mentioned above contains about twenty-five feet.

2. Drawing and Closing Glass Tubing.—Hold one end in each hand and keep the tube rolling continually while holding it in the flame, so as to soften it all around.

When it has become quite soft remove it from the flame and pull. You will readily draw it out, as represented in figure 5. Make a very slight scratch at *a* with a three-cornered file and break the tube at that point. Finish the broken ends by holding them for an instant in the flame. With care you will be able to melt the ends so as to make them smooth, without bending or closing them. The end *ac* will serve many useful purposes as a "dropper-tube," if a small rubber bulb called a "dropper-bulb" is put upon the end *c*. The end *ab* may be used for throwing jets of water, as illustrated in figure 40, p. 29.

FIG. 4.

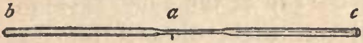


FIG. 5.

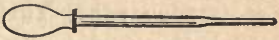


FIG. 6.

One is always obliged to proceed according to the above directions in order to close large tubing; and by this method I have even drawn apart an argand-lamp chimney. It was necessary to smoke the chimney all around first and then to heat gradually with constant rolling.

A very much better way, however, to deal with small tubing is as follows: Hold the tube so that the end projects not more than an eighth of an inch into the flame, and keep it rolling slowly, so as to heat it uniformly on all sides. It will soon close up entirely; or, if you want a tube for throwing jets of water, arrest the process just before the tube is

FIG. 7.

quite closed, leaving a little hole in the end. This

FIG. 8.

method has two advantages over the other, described on p.——. First, this will throw a straight stream, while in most cases the other will not; and, secondly, this will be thick and strong at the end, while the other will be very thin and quite liable to get broken.

3. **Blowing Bulbs.**—In order to blow a bulb at the end of a glass tube, hold the end of the tube, as shown in figure 8, so as to project a slight distance into the flame. Roll it slowly until it is entirely closed and raised to a red-heat. Close the lips air-tight over the other end, remove it from the flame, and quickly force air into it, taking great care to stop blowing before the bulb bursts.

4. **Cutting Glass Tubing, Bottles, etc.**—For tubing under half an inch in diameter use a three-cornered file and give it a sharp, quick push across the tube so as to leave a scratch, or, if the tube is over a quarter of an inch in diameter, file a rather deep gash, then place your thumbs on the opposite side of the tube and pull suddenly as

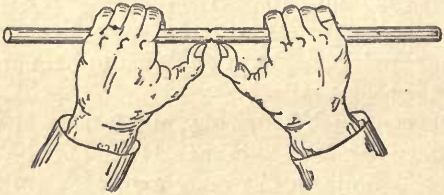


FIG. 10.

if to bend the tube. It will break exactly where you intended and leave an even, smooth surface at the end, having, however, sharp cutting edges. These should be trimmed a little with a file or held in a flame until they are nicely rounded.

For tubing over half an inch in diameter pursue the same plan as for cutting glass bottles. To cut glass bottles: Thrust the stove poker into the fire and, while it is heating, cut quite a deep gash in one side of the bottle with a wet file. This will give the right direction to the crack which you are about to make. Touch the hot poker to the glass at one end of this gash, and a short crack will start in the direction required. Now place the poker so that it will touch the glass about one-eighth of an inch from the end of the crack and it will slowly creep up to the poker. Thus one may lead it at will. The bottom of this bottle will make a glass jar and the top will have a great many uses. See Fig. 12.

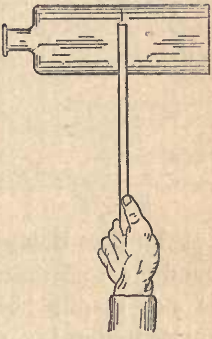


FIG. 11.

For very thick bottles one needs a red-hot iron, but for thin glass it should not be red-hot, because the crack will sometimes run faster than one can control it. With proper care we may cut glass by this method into any shape which we may desire. It is often desirable to mark out the course on the glass with the sharp point of a wet black-board crayon to help the eye in leading the crack. By this method I have cut from a pane of

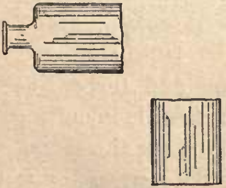


FIG. 12.

glass scale-pans for home-made balances. In this case it is necessary to file a gash at the edge and start the crack there. See Fig. 13.

One may lead a crack around a moderately thin bottle or lamp chimney by a glass rod or tube heated in an alcohol or Bunsen burner flame. This is the most convenient way to do it in the laboratory. The glass rod, being a poor conductor of heat, does not cool off as rapidly as an iron rod, and does not conduct heat to the hand.

FIG. 13.

5. To Bore Holes in Glass.—Break off the tip end of a round file, sometimes called a "rat-tail" file. With this we may readily bore holes in glass. Hold the file as represented in Fig. 14, bearing on heavily with the thumb. Swing the file back and forth horizontally, as indicated by the arrows, at the same time giving it a twisting motion. The file should be frequently dipped into water. A paste made of camphor-gum and turpentine has been widely recommended to assist the file in cutting glass, and many persons have paid heavily for the secret, but it would seem that water answers the purpose quite as well. Indeed, it is probable that anything is equally

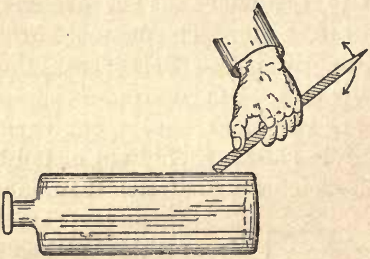


FIG. 14.

good which will retain the little particles of glass that have been chipped off and make them cling to the file so that they may be made to assist in the work. It requires between five and ten minutes of patient work to make a hole through the side of an ordinary bottle. After the hole has been put through the glass it may be trimmed out with a wet, round file to any size desired. Here, however, great care must be exercised to avoid cracking the bottle.

Glass tubing may be made to fit in such a hole water-tight by making the hole a little larger than the tube, then by drawing a small piece of soft rubber tubing over the end of the glass tube and crowding it firmly into the hole. (See figure 15.)

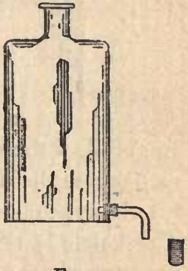


FIG. 15.

A cap which will answer the purpose of a stop-cock in many instances may be constructed as follows: Take a short piece of rubber tubing and plug one end with a very short piece of glass rod or tubing closed at one end in the flame.

It is evident that when one can bend, draw, and close glass tubing, cut glass as he chooses, bore holes in bottles and fit tubes in them water-tight, the way is open to construct an endless variety of apparatus.

PART II. CHEMICAL APPARATUS.

No. 7.* The Oxygen Apparatus.—In the test-tube, figure 16, which suffices for a *retort*, is put about a table-

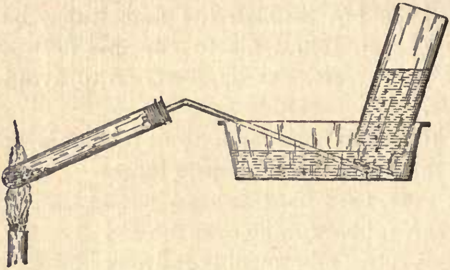


FIG. 16.

spoonful of the usual mixture of potassium chlorate and manganese dioxide. This will yield six or eight bottlesful of oxygen, and is the only *gas holder* that is necessary. The bottle is the only *bell-jar* needed, and the tin basin answers every purpose of a *pneumatic trough.* To hold the apparatus in the hands, moving the test-tube back and forth through the flame, is preferable to the use of a *retort-stand.* The test-tube is 6 × ¾ inches. The stopper is a No. 1 rubber stopper, with one hole in it. The

* All the pieces of apparatus described in these pages were prepared by the author and placed on exhibition at the World's Columbian Exposition, Chicago, 1893. The State of New York purchased from him the entire set, and it is now installed in the Educational Museum, State Capitol, Albany, N. Y. The numbers used in the description of apparatus throughout this book correspond to those which are used to designate the models in that exhibit.

delivery tube is $\frac{3}{16}$ inch glass tubing and is bent according to the directions given on page 5.

A comparison of the expense of this apparatus with that of apparatus much in vogue is given herewith :

COST.

The Conventional Apparatus. Cheapest Kind.		*Home-made Apparatus.*	
A copper retort	$ 2.30	A test-tube, 6×¾ in.	$0.03
A gas holder	15.00	None needed	.00
A bell-jar	.50	A bottle, 8 oz., wide mouth	.05
A pneumatic trough	1.50	A basin, block tin, 6 in.	.05
A retort-stand	.65	None needed	.00
Rubber tubing for connection and delivery tubes	.20	Rubber stopper No. 1	.04
		Delivery tube	.01
	$20.15		$0.18

The same apparatus is used in generating *hydrogen*, *nitrous oxide*, *nitric oxide*, *hydrogen sulphide*, *carbon dioxide*, etc. To generate *chlorine*, substitute the small flask from apparatus No. 18 in place of the test-tube, on account of the frothing produced by that gas.

No 8. Gas Generator.—This apparatus is specially adapted as a hydrogen-sulphide generator. The bottle is an eight-ounce, wide-mouth bottle, with a common cork, through which a hole is cut with a pen-knife, large enough to receive a test-tube. The test-tube fits the hole loosely enough to be easily raised and lowered, but not so as to fall of its own weight. The test-tube has a rubber stopper, through the hole of which a delivery-tube passes. There is a small hole not more than an eighth of an inch in diameter in the bottom of the test-tube, made as follows :

FIG. 17.

The test-tube is held so that the bottom touches the side of a flame, and when the glass at a single point becomes softened, the mouth of the operator is closed over the open end of the tube and the hole is blown while the tube is still held in the flame. The edges of the hole are soon melted back and made smooth by the flame. The bottle is about half filled with dilute sulphuric acid, and a few small lumps of iron sulphide are placed in the test-tube. When the test-tube is pushed down, the acid passes through the small hole in the bottom and comes in contact with the iron sulphide. Hydrogen sulphide then flows through the delivery-tube. When the test-tube is drawn up as represented in figure 17, the acid flows out through the small hole and the generation of hydrogen sulphide ceases. Thus we have a gas generator always ready for use. It may be used for any of the gases which are generated by acids without the application of heat.

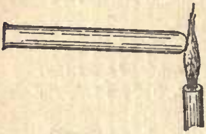


FIG. 18.

Cost.—Bottle from apparatus No. 7.	
Test-tube, $6 \times \frac{3}{4}$ in.	3 cents
Rubber stopper from apparatus No. 7.	
Cork and delivery tube.	7 cents
	10 cents

No. 9. Gas Generator.—This apparatus is convenient when only a small quantity of gas is needed. It consists of a one-ounce wide-mouth bottle and a small glass dish. To generate a bottleful of carbon dioxide, a small lump of chalk or

FIG. 19.

limestone is put into the bottle, and the bottle is filled with dilute acid. The bottle is then covered with the glass dish, and inverted. No delivery-tube and no pneumatic trough are needed.

Cost.—Glass dish	5 cents
	Bottle, 1 oz., wide mouth	2 cents
		7 cents

No. 10. Gas Generator.—This apparatus is specially adapted to the generating of small quantities of gases with a high degree of heat; e.g., the making of oxygen from mercuric oxide. The bottle and glass dish are those used in apparatus 9. Five inches of small glass tubing closed at one end, and bent, as indicated in figure 20, serves as retort and delivery-tube.

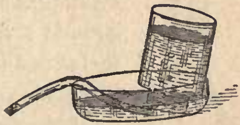


FIG. 20.

No. 11. Gas Generator with a Condensing Chamber.—This apparatus has an important use in experiments in destructive distillation; e.g., if we put paper,

FIG. 21.

wood, or soft coal in the test-tube and heat it we shall get liquid products in the small bottle and gaseous products in the large bottle.

Cost—Test-tube, Rubber stopper No. 1, Tin basin, 8-oz. wide-mouthed bottle, } From apparatus No. 7.
1-oz. wide-mouthed bottle from apparatus No. 9.

Rubber stopper No. 3 with two holes	7 cents
Delivery tubes	2 cents
	9 cents

No. 12. Apparatus for Showing that a Portion of the Air is Consumed in Combustion.—A strip of tin is bent at a right angle at the lower end so as to support a small piece of a taper. The upper end is also bent at a right angle and is tacked to the under surface of the rubber stopper, which it protects from the flame. Lime-water is used in the tumbler beneath the chimney to absorb the products of combustion. The candle attached to the stopper is taken out, lighted, and replaced. Thus a portion of the air is not lost from the chimney by expansion, as is usually the case when a bottle is inverted over a lighted candle in a dish of water.

FIG. 22.

Cost.—Lamp-chimney	5 cents
Rubber stopper No. 7	20 cents
Tumbler	5 cents
	30 cents

No. 13. Apparatus for Determining the Proportion of Oxygen in the Air.—A small piece of clean phosphorus is placed upon the wire-shelf and the test-tube is inverted over it, with its mouth dipping into the water beneath. After standing thus for a day or two the water will be found to have risen so as to occupy about

one fifth of the volume of the test-tube. Measurements carefully made were found to be, as shown in the figure,

$$\frac{\text{Vol. of oxygen}}{\text{Vol. of air}} \text{ as } \frac{1.2}{5.7} = 21 \text{ per cent.}$$

At the close of the experiment the flame of a lamp may be directed toward the upper end of the test-tube until the phosphorus melts and runs down the wire without burning or producing the white fumes

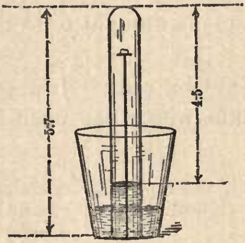


FIG. 23.

FIG. 24.

which would appear if oxygen were present. The test-tube may now be lifted, while the phosphorus is thus heated above its kindling temperature, and it will immediately spring into a flame.

The wire support for the phosphorus is made of No. 18 copper wire, which is easily bent with the fingers in the form represented by figure. 24.

Cost.—Test-tube from apparatus No. 7.
Small tumbler........................ 5 cents

No. 14. The Miner's Safety Lamp.—Wire gauze, such as is used for milk-strainers or fine sieves (30 or 40 meshes to the inch), six inches square, is rolled into a cylinder about an inch in diameter and tied with wire, common corks are fitted nicely into the ends, a very small taper is fastened to the lower cork by a drop of its own melted wax. Coal-gas, or a little ether, is put into the large bottle, which in this case represents a coal mine in which a combustible gas has collected; the candle is lighted and put into the wire-gauze cylinder and lowered into the bottle without setting fire to the gas, but if the uncovered flame is brought to the mouth of the bottle a flash occurs.

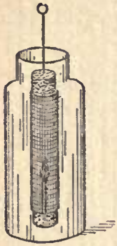


FIG. 25.

A little lime-water is then put into the bottle, showing the presence of carbon dioxide, which has been formed by the combustion.

Cost.—Wire gauze, cork, and taper....	15 cents
32-oz. wide-mouth bottle.......	17 cents
	32 cents

No. 15. Test-tube Rack.—The rack is made of thin strips of wood, two inches wide; the uprights four and a half inches high and the horizontal strips twelve and thirteen inches respectively. In the upper strip, six holes are bored with a seven-eighth-inch bit. In the lower

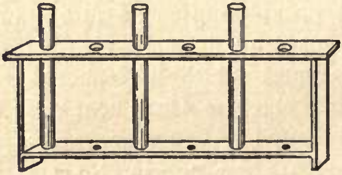


FIG. 26.

strip, underneath each of these holes, a cup is made with a countersink to receive the lower end of the test-tube.

No. 16. Test-tube Tongs.—The test-tube tongs are made of two strips of wood each about nine inches long and half an inch thick, cut as represented in figure 27. They are held together by stout rubber bands—no hinge is needed—which are represented in the figure as placed so as to cause the tongs to close. They are opened by a slight pressure of the hand upon the large end.

Fig. 27.

If, however, one prefers tongs which ordinarily remain open and require a slight pressure of the hand to close them, the rubber bands may be moved somewhat nearer the large end and the tongs will so operate.

No. 17. Blow-pipe.—The blow-pipe is made of two pieces of glass tubing, each about four inches long, one of which is nearly closed at one end, as described on page 7. The two pieces of glass tubing are connected by a piece of soft rubber tubing. This enables one to direct the stream of air from the blow-pipe as he chooses.

Fig. 28.

Cost.—Rubber tubing from apparatus No. 8.
Glass tubing........................... 1 cent

No. 18. Distilling Apparatus.—This is used in making nitric acid, hydrochloric-acid solution, ammonia solution, and bromine, as well as separating alcohol from water and obtaining from solution distilled water in small quantities.

A test-tube is sometimes used in place of the flask.

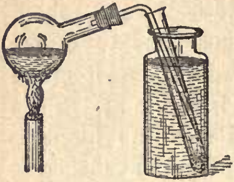


Fig. 29.

The latter, however, is preferred when frothing is liable to occur. The delivery-tube is made of such a length as to reach within about one inch of the bottom of the test-tube in which the vapors are condensed. The distillate which is collected in the test-tube is never allowed to cover the end of this delivery-tube—the amount needed for each pupil is very small.

To make hydrochloric acid or ammonia solution, a little water is put into the test-tube, not quite up to the end of the delivery tube. This water absorbs the gas as fast as it is generated.

Cost.—8-oz. wide-mouth bottle, Test-tube, Rubber stopper, No. 1,	From apparatus No. 7.
2-oz. flask	11 cents
Delivery tube	1 cent
	12 cents

No. 19. Apparatus to Show that Water may be Produced by Passing Hydrogen over Hot Copper Oxide.—The hydrogen is allowed to flow through the tube for a time to show that moisture is not deposited from the gas, and hence no drying tubes are needed. A flame is then placed under the end of the tube containing the copper oxide and water is produced.

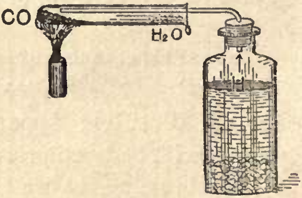


Fig. 30.

Cost.—	8-oz. narrow-mouthed bottle	5 cents
	Rubber stopper No. 0, with one hole	3 cents
	Delivery tube	1 cent
		9 cents

No. 20. Apparatus to Show that Hydrogen may be Produced by Passing Steam over Hot Iron Filings.—In using the apparatus one hand holds the tin basin and steadies the bottle and the other hand holds the lamp under the end of the test-tube. It is preferable

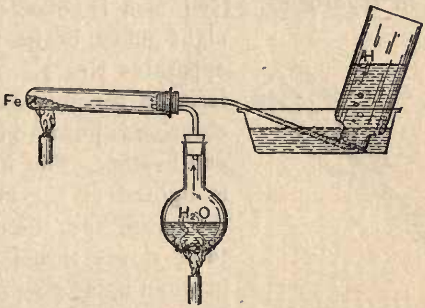


FIG. 31.

not to lock the apparatus in a support stand, but to have it entirely in hand. If the rubber stopper is pressed firmly into the mouth of the flask, there is no danger of the flask falling without a support.

Hydrogen sulphide may be collected in the bottle by generating hydrogen in the flask and heating sulphur in the test-tube. In this case the melted sulphur should be kept in the end of the test-tube remote from the rubber stopper by tilting the apparatus slightly.

Cost.—8-oz. wide-mouth bottle, Tin-basin, Test-tube, Rubber stopper No. 1 with one hole,	From apparatus No. 7.	
2 oz. flask from apparatus No. 18.		
Rubber stopper No. 1 with two holes		4 cents
Delivery-tubes		2 cents
Extra lamp		45 cents
		51 cents

No. 21. Apparatus to Show that Oxygen or Chlorine will Burn in Hydrogen.—Hydrogen is collected in the eight-ounce bottle by using apparatus No. 7. The material to generate oxygen or chlorine is put into the flask and heated. The hydrogen is lighted at the mouth of the bottle and the delivery-tube slowly thrust up into it, when a flame will be seen burning at the end of the delivery-tube. The upper end of the bottle is held in one hand, while the neck of the flask is held in the other. The apparatus is tilted to prevent the burning of the hands by the flame.

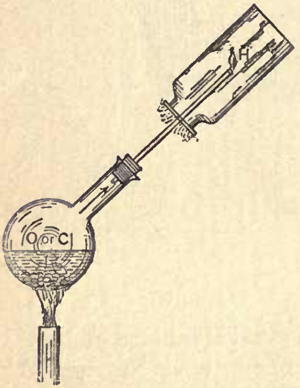


FIG. 32.

To burn hydrogen in oxygen or chlorine, we have merely to substitute the delivery-tube from the apparatus represented in figure 29, collect oxygen or chlorine in the eight-ounce bottle by using apparatus No 7, and generate hydrogen in the flask. The hydrogen must be allowed to flow rapidly for a few minutes to remove air from the flask, in order that there may be no explosion. We fill the flask one-quarter full and add about one-third as much sulphuric acid. Drop in granulated zinc while the mixture is warm, and the hydrogen will flow rapidly. The hydrogen flame burning in the bottle produces a musical sound.

Cost.—8-oz. wide-mouthed bottle, } From apparatus No 7.
Rubber stopper No. 1, }
2-oz. flask, from apparatus No. 18.
Delivery-tube.................................1 cent.

PART III. PHYSICAL APPARATUS.

No. 22. Apparatus to Show that Air Occupies Space to the Exclusion of Other Things.—The funnel is made of paper. The opening in the lower end is about one-eighth of an inch. Dip the funnel in water and fit it air-tight in the neck of the bottle. The funnel may be filled with water, and after about a tablespoonful has passed into the bottle it will cease to flow, unless a bubble of air comes out, when only the same amount of water will pass in. Put water on the top of the bottle, outside of the funnel. (If the funnel was sufficiently wet this will collect there of its own accord.) Now press the side of the funnel in a little, so that you may see a little air bubble out through the water. Notice that at the same time a small amount of water flows from the funnel into the bottle.


FIG. 33.

No. 23. Apparatus to Show that Invisible Substances May Have Weight.—Make a paper box five inches long, three inches wide, and two and one-half inches deep, from a sheet of writing-paper, letter size, or 8 × 10. Place this upon one end of a foot rule, laid across a three-cornered piece of wood, the thickness of which should be not more than one-quarter of an inch. While it is impossible to

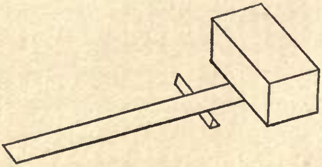


FIG. 34.

balance the ruler across this piece of wood, it may be so nearly balanced as to tip either way with the addition of an exceedingly small weight. Put a few drops of ether into a tumbler, and let it stand a few minutes until they evaporate and the tumbler is filled with ether vapor, then hold the tumbler as if in the act of pouring something from it into the box. Soon the box will press its end of the ruler down, and if a lighted match is brought to its mouth a flash occurs, showing that the ether vapor was poured into it.

No. 24. Receiver for Experiments in Rarefied and Condensed Air.—Figure 35 represents a 32-ounce wide-mouthed bottle, E. & A. style. In its mouth is a No. 10 rubber stopper, one hole of which is plugged with a short piece of glass rod, while the other carries a bent glass tube, over which is drawn a piece of heavy rubber tubing, called "pressure tubing," about eighteen inches long. This answers all the purposes of a receiver. For very many experiments it is sufficient to apply one's mouth to the rubber tube and exhaust or compress the air in the bottle by the use of the lungs. With practice, the average person may thus reduce the tension of the air to seven or eight pounds per square inch, or increase it to seventeen or eighteen pounds per square inch. When a greater degree of exhaustion or compression of air is needed, the rubber tube is attached to one or the other nipple of a combination of air-

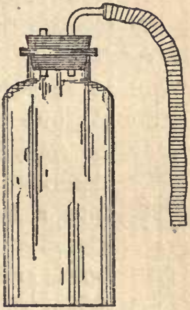


FIG. 35.

pump and condenser, sold by the Franklin Educational Company, of Boston, for $3.

Cost.—32-oz. wide-mouth bottle, E. & A. style, from apparatus No. 14.
Rubber stopper No. 10........................39 cents
Rubber "pressure" tubing, 18 inches....... 24 cents

63 cents

Nos. 25, 26, and 27. Apparatus to Show that the Volume of Air Varies as the Pressure upon it Increases or Decreases.—No. 25 consists of a one-ounce wide-mouth bottle, over the mouth of which rubber cloth is tied *air-tight.* The bottle is then placed in the receiver, No. 24, and when the air in the receiver is rarefied the rubber cloth bulges outward, and when air is condensed in the receiver the rubber cloth sags into the neck of the small bottle.

No. 26 consists of a one-ounce narrow-mouth bottle (figure 36), into the mouth of which a glass tube, three or four inches long, is fitted by the method described on p. for inserting a glass tube into a hole in a bottle. This tube is nearly closed at the upper end. Water is put into the bottle and the lower end of the tube dips into it. When this apparatus is placed in the receiver and the air rarefied water spurts out of the small bottle as a fountain. When air is allowed to rush into the receiver again, it is seen to enter also the small bottle by bubbles which pass through the water. When air is condensed into the receiver, it is seen to enter the small bottle and, when the compressed air is allowed to flow out of the receiver,

FIG. 36.

water again spurts from the small bottle. In figure 37 the glass tube is inverted, so that the constricted end is inside the bottle, and a little water is put into the receiver so as to seal the outer end of the tube. A fountain will play into the small bottle when air is compressed into the receiver, and air will pass out from the small bottle when it is allowed to flow out of the receiver. It continues to pass out of the small bottle as we exhaust it from the receiver, but the fountain plays again in the small bottle when the air is allowed to enter the receiver.

FIG. 37.

No. 27 consists of a one-ounce narrow-mouthed bottle, into the mouth of which a bent glass tube is fitted by the method referred to above. Water is put into the small bottle and the glass tube dips into it. When this apparatus is placed in the receiver, (figure 38), the outer end of the tube is covered with water, and when the air in the receiver is rarefied water is forced out of the small bottle by the tension of the air contained in it. When air is allowed to rush into the receiver again water flows into the small bottle. If air is compressed into the receiver, water flows into the small bottle, and, when the compressed air is released, water passes out from the small bottle.

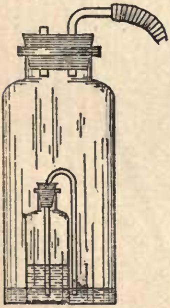


FIG. 38.

Cost.—	1-oz. narrow-mouthed bottle	2 cents
	Tubing	2 cents
	Rubber cloth	2 cents
	Receiver from App. No. 14 and 1-oz. wide-mouthed bottle from App. No. 9.	
		6 cents

No. 28. Apparatus to Demonstrate that the Volume of a Gas Varies Inversely as the Pressure upon it.—A glass tube, whose inside diameter is one-quarter of an inch, and whose length is about fifty-two inches, is closed at the end *a* (figure 39), and is bent so that *ab* is 3 inches, *bc* is 2 inches, *cd* is 34 inches, *de* is 2 inches, and *ef* is about 11 inches long. The end *f* is left open.

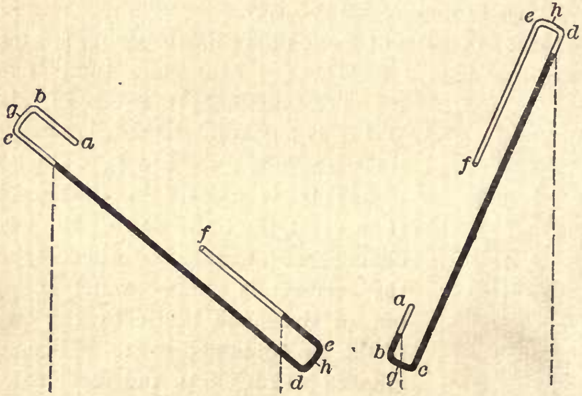


FIG. 39.

The tube is fastened to a strip of board to protect it from injury. Mercury is put into the tube so that the column when horizontal extends from *g* to *h*. In handling mercury we use a dropper-tube such as is illustrated in figure 6, p. 7.

To find volumes corresponding to pressure greater than an atmosphere the end *h* of the apparatus is raised to various positions and the vertical height above the table of the mercury column in each arm is measured.

To find volumes corresponding to pressure less than an atmosphere, the end *g* is raised and measurements taken as above.

Cost.—	Glass tubing....................	18 cents
	Mercury.........................	35 cents
		53 cents

No. 29. Apparatus to Show a Fountain Caused by Atmospheric Pressure and a Fountain Caused by Compressed Air.—It consists of a 16-ounce narrow-mouthed

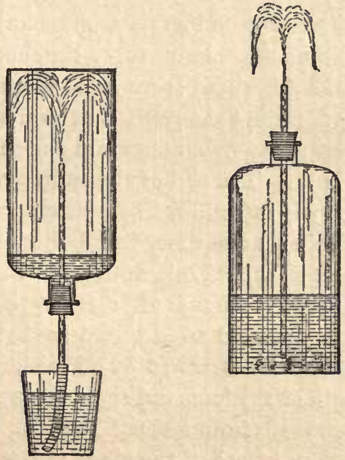


FIG. 40.

bottle, a No. 1 rubber stopper, a piece of glass tubing nine inches long, nearly closed at one end, a short piece of rubber tubing, and a tumbler. Either the lungs of the operator or the air-pump mentioned on p. 25 may be used to rarefy or condense the air in the bottle, and thumb and finger applied to the rubber tubing serve as a stop-cock.

Problems as to what this apparatus would do if taken up in a balloon or down in a coal mine are of interest, also its relation to air-guns, spurting oil-wells, "soda-water fountains," "syphon" bottles, etc.

Cost.—Rubber stopper No. 1 from apparatus No 7.
Rubber tubing from apparatus No. 8.
Tumbler from apparatus No. 12.

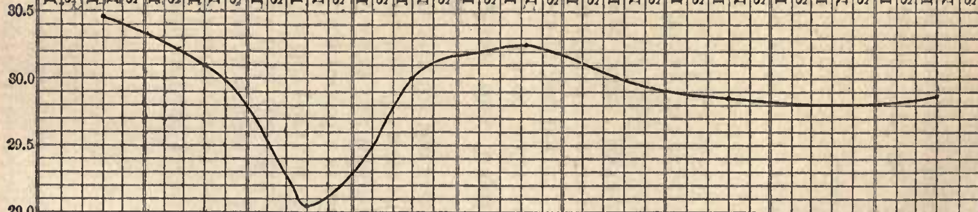
16-oz. narrow-mouthed bottle......	5 cents
Glass tube........................	1 cent
	6 cents


FIG. 41.

No. 30. Barometer.—A glass tube, having an inside diameter about three-sixteenths of an inch and a length about forty-three inches, is closed at one end in the flame, and bent so that the long arm is about thirty-five inches and the short arm about six inches. The end of the short arm is left open. Mercury is introduced by a dropper tube, three or four inches at a time, and boiled by passing the barometer tube back and forth through a flame each time a charge of mercury is added. The tube is fastened to a board-back for protection, and a scale is attached by which one may readily read the length of the long and short arms of the mercury columns, measured from a small shelf at the bottom of the board. The length of the short arm subtracted from

COMPARISON OF THE BAROMETER AND THE WEATHER, 3 P.M.

Date	Name of Observer	Long Arm	Short Arm	Difference	Newspaper Report	State of Weather
Oct. 1	Willie Graham	33.00	2.55	30.45	30.42	Clear
Oct. 2	Frank Clark	33.02	2.95	30.07	30.08	Cloudy
Oct. 3	Rose Willis	32.70	3.65	29.05	29.00	Rainy
Oct. 4	Mildred Foote	33.00	3.00	30.00	30.03	Cloudy
Oct. 5	John Ingham	33.09	2.85	30.24	30.30	Clear
Oct. 8	Raymond Bunce	32.98	2.99	29.99	29.94	Clear
Oct. 9	Fanny Davis	32.92	3.00	29.92	29.86	Cloudy
Oct. 10	Ralph Goodell	32.86	3.06	29.80	29.77	Clear
Oct. 11	Edith Sampson	32.89	3.05	29.84	29.84	Clear



NAME OF OBSERVER.

the length of the long arm gives the height of the mercury column, which is balanced by atmospheric pressure.

Cost.—	Glass tubing........................	7 cents
	Mercury..........................	25 cents
		32 cents

The records given herewith, on page 31, are samples of such as were kept upon this barometer by a primary class of the third grade (third year in school). The teacher instructed one pupil how to take the observations and record them, and the next day this pupil, at the appointed time (close of the session), instructed a second pupil to do the same, who, in turn, upon the following day, instructed a third pupil, and so on. The teacher obtained from the evening paper a report for the same hour, and recorded it the next morning.

No. 31. Apparatus to Show that Liquid Pressure Increases with the Depth.—Three holes are bored in the side of a 32-ounce wide-mouthed bottle. Short tubes nearly closed at their ends are fitted into these holes, and caps are provided for these tubes according to the method described on p. 11. To keep the water in this bottle at a constant level during the experiment, a 16-ounce narrow-mouthed bottle, whose neck has been cut off (p. 9), is filled with water and inverted over it.

Cost.—	32-oz. wide-mouthed bottle.......	17 cents
	16-oz. narrow-mouthed bottle.....	5 cents
	Tubing........................	3 cents
		25 cents

No. 32. Apparatus to Show that the Increase of Liquid Pressure is Proportional to the Depth.—A

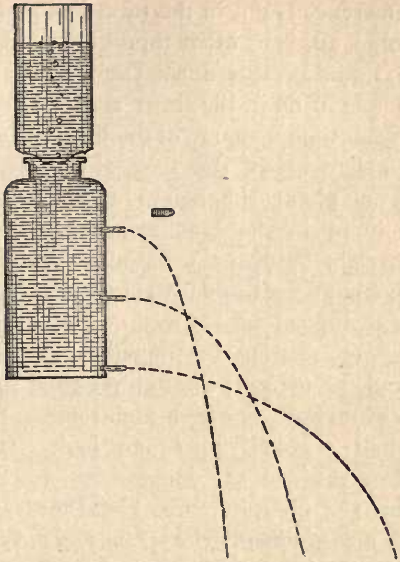


FIG. 42.

glass tube about twenty-two inches long is bent so that the long arm is about sixteen and the short arm about four inches long. Both ends are left open. The tube is fastened to a board-back, and a scale for measurement is placed alongside of each arm. The whole is attached to a board base sufficiently broad to make it stand firmly. The base has an elevated margin, so as to form a tray to catch the mercury which may be spilled by accident.

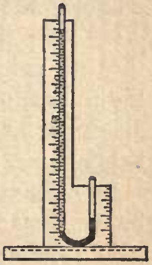


FIG 43.

A little mercury is put in the tube first and afterwards water, alcohol, ether, or other liquid is added to the long arm. The liquid presses down the mercury in the long arm and forces it up in the short arm. Three readings are taken each time a charge of the liquid is added; one giving the height above the base of the mercury in the short arm; one giving the height above the base of the mercury column in the long arm, and one giving the height above the base of the liquid column in the long arm. The second reading subtracted from the third gives the length of the column of water, or other liquid used, and the second reading subtracted from the first gives the length of the mercury column required to balance it. A column of mercury one inch high represents a pressure of about half a pound per square inch. It requires a column of water about 13.7 inches high, and a column of alcohol about 17 inches high to give the same pressure. From such measurements the specific gravity of mercury and alcohol or other liquids is obtained.

The water-column is extended and enlarged by putting a rubber stopper into the small end of a common lamp-chimney and thrusting the end of the long arm of the glass tube through the hole in the stopper. Water is then poured into the chimney. In spite of the fact that the volume of water is so greatly increased, the pressure, measured as before, is found to be proportional to the depth alone.

By means of rubber tubing this pressure gauge may be connected with the spout of the bottle described on p. 11. After all the air is dislodged from the tubes, the bottle may be raised and lowered to various positions, and measurements taken to show that the pressure of a liquid is proportional to the depth measured vertically, no matter what is the size or shape of the vessel containing the liquid.

By means of rubber tubing this pressure gauge is connected with gas-pipe, steam-pipe, water-pipe, or the lungs, and the pressure in terms of pounds per square inch determined.

By means of rubber tubing a glass tube is connected with this pressure gauge, and the glass tube is dipped to various depths in various liquids to determine the buoyant force or upward pressure in liquids. By the same experiments we calculate the specific gravity also of various liquids.

Cost.—Glass, wood, and mercury........ 10 cents.

No. 33. Apparatus to Show that at Any Given Depth in a Liquid, the Pressure is the Same in All Directions.—Rubber cloth is tied water-tight over the bottom of a lamp chimney. Three glass tubes pass through the rubber stopper, each open at both ends. The lower ends of all are on the same level; one points downward, another sidewise, and the third upward. When a finger presses upon the rubber cloth the water rises to the same height in all the tubes. The tubes act as pressure gauges, and the height of the water-column may be translated readily into pounds pressure per square inch.

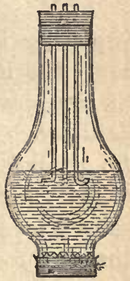


FIG. 44.

Cost.—Glass tubing	4 cents
Rubber stopper No. 7, with three holes	20 cents
Rubber cloth	5 cents
Lamp chimney from Apparatus No. 12.	
	29 cents

No. 34. Apparatus for Illustrating Buoyancy and the Transmission of Pressure Through Liquids.—A small pill bottle about half full of water and half full of air is inverted in water in a lamp chimney. There is no cork in the vial. The proportion of air to water in the vial is so carefully adjusted that the slightest change of pressure or temperature will cause it to sink or float. When a little pressure is exerted upon the rubber cloth or the rubber stopper of the chimney, the pressure is transmitted through the liquid to the air in the small vial, causing it to contract, as is seen by the rising of the water in the small bottle. The air, now displacing less water, no longer buoys up the small bottle and it sinks. When the pressure is removed the air recovers again its original volume, demonstrating its elasticity. The weight of the water now displaced by the air and the glass of the small bottle being equal to or greater than the weight of the small bottle, it is again buoyed up. If the small bottle sinks at night when the room is cold it will rise during the day when the room is warm.

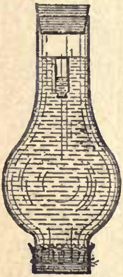


FIG. 45.

Lamp chimney and rubber stopper from apparatus No. 12.

No. 35. Apparatus to Show the Transmission of Water Pressure by an Air Column.—The lower bottle may be placed upon the table or floor and the other bottles held, one in each hand.

If the bottle *A*, from which the fountain flows, is raised or lowered there is no change in the force of the fountain, because no change in the water pressure which produces it, but if the bottle *B* which is held in the other hand is raised or lowered it changes the height of the fountain. This piece of apparatus is calculated to dispel some of the fallacious notions to which the mystical apparatus called "Hero's Fountain" has given rise.

Cost.

16-oz. narrow-mouthed bottle from apparatus No. 29.	
2-16-oz. narrow-mouthed bottles..................	10 cents
Rubber stopper No. 1 with two holes...............	4 cents
Rubber stopper No. 1 from apparatus No. 20.	
Glass tubing 2 feet........	4 cents
Rubber-tubing from apparatus No. 95.	
	18 cents.

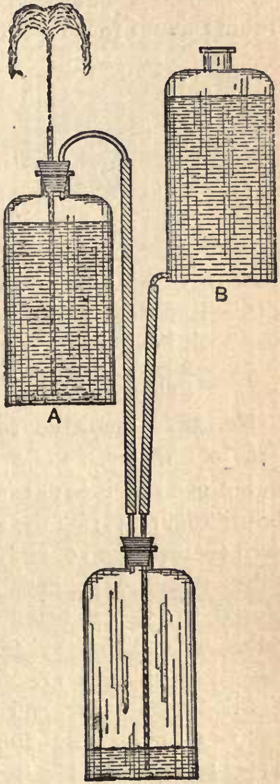


FIG. 46.

No. 37a. Apparatus to Illustrate the Total Fluid Pressure in a Closed Vessel.—A tin lard pail cover whose sides are straight has a rubber cloth tied over it so as to make an air-tight space inside. A short piece of glass tubing is fitted into its side by the method described on page 11, and a piece of rubber tubing about four feet long is attached to this. A book is laid across over the rubber cloth and weights laid upon it. The mouth may be used upon the end of the rubber tube and a weight of many pounds lifted by the force of the breath. The rubber tube may be connected with the bottle of water described on page 11, and a weight of many pounds upon the book be lifted by the pressure of the column of water.

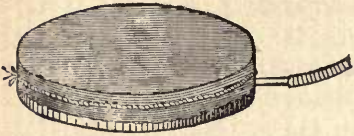


FIG. 47.

Cost.—Rubber cloth.............................. 10 cents.
Rubber tubing from apparatus No. 95.

No. 38. Apparatus to Illustrate the Reaction of a Jet of Water.—Four holes are bored in a 16-ounce narrow-mouthed bottle (figure 48) by the method described on page 10, and short bent tubes whose outer ends are nearly closed (p. 7) are fitted into these holes water-tight by the method described on page 11. The bottle is filled with water and suspended by a string. The four jets of water cause the bottle to revolve.

Cost.—16-oz. narrow-mouthed bottle...............	5 cents.
Tubing...............	2 cents.
	7 cents.

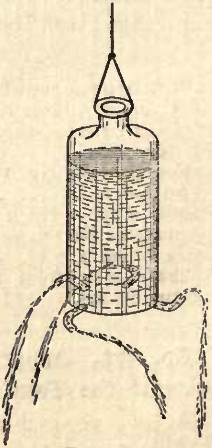


FIG. 48.

No. 39. Student's Lamp.—In figure 42, page 33, the inverted bottle of water used for the purpose of keeping the liquid at a constant level suggests a piece of apparatus for explaining the student's lamp. The bottom is cut from a 16-ounce narrow-mouthed bottle (p. 9), and a bent glass tube is put through the hole of the rubber stopper (figure 49). An 8-ounce bottle of water is inverted in this bottle. Its mouth has no stopper. The water stands in the bent tube on a level with the mouth of the smaller bottle. Take water from the outer end of the bent tube with a dropper tube and bubbles of air will be seen to rise into the smaller bottle and just enough water will pass out to restore the level.

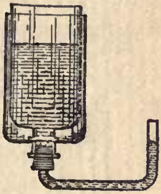


FIG. 49.

Cost.—	Glass tubing..................................	1 cent
	16-oz. narrow-mouthed bottle................	5 cents
	8-oz. narrow-mouthed bottle from apparatus No. 19.	
	No. 1 rubber stopper from apparatus No. 7.	
		6 cents

No. 40. Fountain Sponge Cup.—Two cups are made by cutting the bottom portion from two 8-oz. wide-mouthed bottles. Holes are bored in these, and they are connected by a short piece of glass tubing (p. 11). In one of these cups an 8-oz. wide-mouthed bottle of water is inverted. The water flows through the short tube into the other cup, in which a sponge is kept. A constant level of the liquid is thus maintained, and the

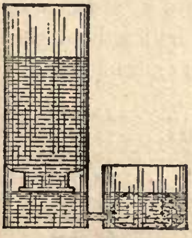


FIG. 50.

sponge is kept moist. Ink-wells are constructed upon the same principle.

Cost.—2 8-oz. wide-mouthed bottles.......... 12 cents
1 ditto from apparatus No. 7.

No. 41. Lifting Pump.—A No. 9 rubber stopper fits into the bottom of a small-sized Argand lamp-chimney, figure 51. One hole is plugged, and into the other is thrust a short piece of glass tubing, with a piece of rubber-tubing to lead down into the cistern. About one inch and a half is cut from the top of the chimney (p. 9). Below that the chimney is found to be of nearly uniform diameter. A No. 5 rubber stopper is used for the piston and is wound with soft cotton cord to make it fit nicely. Small pieces of rubber cloth are used as valves. A glass rod is used to move the piston. Knobs are made upon the ends of it by softening them in a flame and pressing them while they are soft against a hard surface. Waxed thread is wound tightly around the rod, just above the piston, to prevent its slipping downward. A No. 6 rubber stopper is put in the top of the chimney, and a bent glass tube passing through one of its holes serves as a spout.

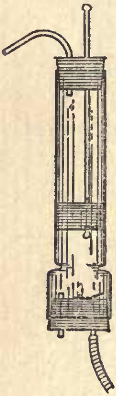


FIG. 51.

Cost.—Argand lamp chimney..................		10 cents
Rubber stopper No. 9 with two holes....		31 cents
" " 5 " " "		10 cents
" " 6 " " "		14 cents
Sundry items........................		3 cents
		68 cents

No. 42. Force-Pump.—To make a force-pump the plug is removed from the lower stopper of apparatus No. 41 and thrust into the hole of the piston under the valve. An air-chamber is made from a 1-oz. wide-mouthed bottle, figure 52. Through one hole of its stopper a bent glass tube passes, having the outer end nearly closed, for throwing jets of water.

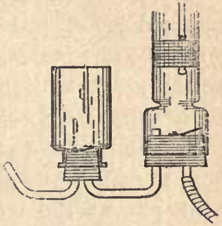


FIG. 52.

A valve like that used in apparatus No. 41 covers the other hole of the stopper upon the inside of the bottle, and from this hole a bent glass tube passes and connects this air-chamber with the lamp-chimney pump.

Cost.—1-oz. wide-mouthed bottle from apparatus No. 9.
Rubber stopper No. 3 from apparatus No. 11.
Glass tubing.................................. 1 cent

No. 43. Apparatus to Illustrate the Moment of a Force.—A strip of wood thirteen inches long, quarter of an inch thick, and three-eighths of an inch wide, is pivoted in the middle upon a common pin, figure 53. Hooks made of pins are inserted along the lower edge, at distances one inch apart. Coarse copper wire, No. 12, is cut into lengths exactly three inches long. These are

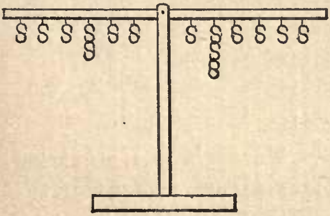


FIG 53.

bent in the form of the letter S. Two of these weights hung upon the first pin at the left balance one weight hung upon the second pin at the right. Three weights upon the first pin at the left balance one weight upon the third pin at the right. Four weights upon the first pin at the left balance one weight upon the fourth pin at the right. Five weights upon the first pin at the left balance one weight upon the fifth pin at the right. Six weights upon the first pin at the left balance one weight upon the sixth pin at the right. Two weights upon the third pin at the left balance three weights upon the second pin at the right, etc.

No. 44. Apparatus Illustrating the Second Law of Motion.—To a thin strip of wood eight inches long, one inch wide, and three-eighths of an inch thick, figure 54, is fastened a small block two and a half inches long and one inch square at the end, with a quarter-inch hole

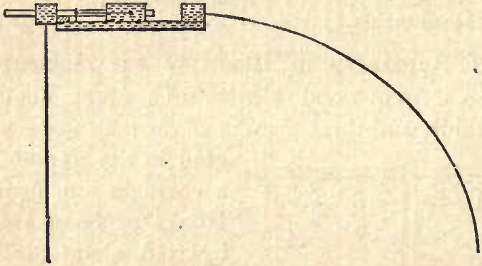


FIG. 54.

made through it lengthwise. Through this a quarter-inch dowel-rod eight inches long passes. There are two blocks of wood, each a cubic inch in size, through one of which a quarter-inch hole is bored, so that it may be suspended upon the dowel-rod. By means of rubber bands the dowel-rod is made to act as a spring-gun. It sets both blocks free to fall at exactly the same instant, but at the same time projects one of them horizontally. Both blocks, however, reach the floor at exactly the same instant.

No. 45. Centre-of-Gravity Disk.—In a flat cork saw on one side a gash and fill it with a piece of sheet-lead, figure 55.

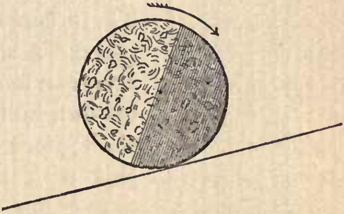


FIG. 55.

No. 46. Apparatus to Show the Specific Gravity of Liquids when Measured by their Buoyant Force.—An 8-ounce wide-mouthed bottle contains the liquid whose specific gravity is to be found. A test-tube containing shot, to make it keep the upright position, floats in the liquid. With it very accurate results have been obtained by high-school pupils. By putting more or less shot into the test-tube it is made to serve for liquids of all densities. By reason of the fact that the glass is not attacked by acids and is easily kept clean, it proves to be a very convenient form of apparatus.

FIG. 56.

No. 47. Apparatus to Show the Specific Gravity of Liquids when Balanced Against Atmospheric Pressure.—A glass T-tube is bent as shown in figure 57, and by means of rubber tubes it is connected with two glass tubes, each about one foot long. These dip down into two test-tubes. The glass T-tube is wired securely to a board back supported upon a board base. A scale is fastened to the back between the glass tubes. The rubber-tube connections permit the lower end of the glass tubes to be swung outward, so that the test-tubes may be changed at pleasure. These contain the liquids to be compared. A short glass at the upper end serves as mouth-piece (each pupil has his own individual mouth-piece) and a short piece of rubber tubing connects this with the T-tube. The air is drawn out with the mouth, and this rubber tube is pinched with thumb and finger while the height of the liquid columns is measured.

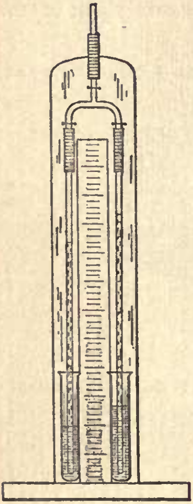


FIG. 57.

Cost.—	T-tube.............	15 cents
	Glass tubing.......	4 cents
	Rubber tubing.....	5 cents
	Test-tubes.........	6 cents
		30 cents

No. 49. Apparatus to Illustrate Osmose.—A gold-beater's-skin bag is tied over the end of a glass tube, figure 58, and this by means of a short piece of rubber tubing is connected with a bent glass tube which passes through a stopper in an 8-ounce wide-mouthed bottle. The other hole of the stopper is left open. By means of a dropper-tube, the end of which is drawn out into a long, slender tube, a thick sugar syrup is introduced into the

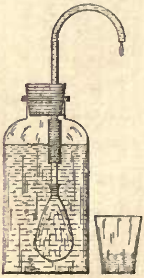


FIG. 58.

bag through the short glass tube. The connection with the larger tube is then made again, and it is allowed to hang in the bottle for a time to insure that there is no leaking through the bag. Then water is poured into the bottle to cover the bag. Immediately the liquid begins to rise in the glass tube and after a time flows over the top, although the tube may be very long and very large. An argand-lamp chimney is frequently used for the tube with the same result. If the end of the glass tube is sealed up, the bag will swell and burst. If the sugar syrup is put into the bottle outside of the bag and water is put inside the bag, it will shrink and become very small. The same phenomenon is to be noticed when prunes or berries are put into water or sugar syrup.

Cost.—Gold-beater's skin bag........................	15 cents
Tubing....	5 cents
Rubber stopper No. 7 with two holes........	20 cents
8-oz. wide-mouthed bottle from apparatus No. 7.	
Small tumbler from apparatus No. 13.	
	40 cents

No. 51. Apparatus for Illustrating the Formation of Ice Crystal in a Snowstorm.—An 8-ounce flask is filled to the neck with a concentrated hot solution of ammonium chloride in water. Upon cooling, crystals rapidly form and fall through the solution like snowflakes. They grow larger as they fall. The round flask magnifies them, so that they may be seen when very minute. The flask is closed with a rubber stopper to prevent evaporation, and the solution may be kept any length of time. Whenever it is desired to repeat the experiment the crystals are readily

FIG. 59.

dissolved again by passing the flask back and forth through the flame of an alcohol-lamp or Bunsen-burner.

Cost.—8-oz. flask	15 cents
Rubber stopper No. 5 without holes	10 cents
	25 cents

No. 53. Apparatus to Illustrate the Unequal Expansion of Different Metals when Heated.—A piece of wood is cut as represented in figure 60, and strips of tin (sheet iron) and brass are screwed fast to it. When it is held so that the flame plays upon these strips of metal they curve, indicating that they grow longer when heated, but the strip of brass always curves more than the other.

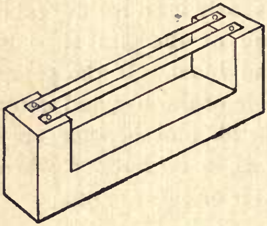


FIG. 60.

No. 54. Apparatus to Illustrate the Expansion of Liquids by Heat—Thermometer.—The glass tube, figure 61, has an inside diameter of about one-eighth of an inch. Its length is not less than a foot. The flask has a capacity of two ounces and is filled with water. When the rubber stopper carrying the tube is inserted and pushed firmly into the neck all the air is driven out and the water is driven a little way up the tube. If the flask is now held in a flame the water rises slowly up the tube, showing expansion in its volume. By using a tube of smaller diameter and a flask of larger size, the thermometer becomes more sensitive, i.e., its

FIG. 61.

rise and fall can be noted for smaller changes of temperature.

Cost.—Glass tube.................................... 2 cents
Rubber stopper No. 1 from apparatus No. 7.
Glass flask, 2-ounce, from apparatus No. 18.

Nos. 55 and 55a. Apparatus to Illustrate the Expansion of Air by Heat—Air Thermometer.—Apparatus No. 55 is an 8-oz glass flask, with rubber cloth tied air-tight over its mouth. When the air is heated the rubber cloth swells upward, indicating the expansion of the air. When the flask is plunged into cold water the rubber cloth sags inward, indicating the contraction of the air.

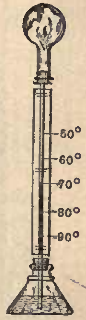


FIG. 62.

Apparatus No. 55*a* is the same flask and tube as that described under No. 54. It is inverted, and the glass tube passes through an ordinary cork and dips into water in an ink-bottle, figure 62. A flame brought near the flask causes the air in it to expand, and bubbles pass out through the water. When the air cools water rises in the tube. A strip of paper is attached to the tube by mucilage, and on it is marked the height to which the water rises when the temperature, as indicated by an ordinary thermometer, corresponds to fifty, sixty, seventy, eighty, and ninety degrees Fahrenheit.

Nos. 56 and 57. Apparatus to Show How Air Currents Are Produced by Heat.*—Apparatus No. 56 consists of a pasteboard box-cover in which two holes are cut, and over each of these a lamp-chimney stands, figure

* Borrowed from the author's "Simple Experiments."

63. A lighted candle is under chimney *a*. When smoke from burning paper is brought to the top of chimney *b* there is found to be a strong *downward* current in it. The smoke is carried along under the box-cover and up chimney *a*.

Cost.—2 Argand lamp-chimneys........ 20 cents.

Apparatus No. 57 consists of a common lamp-chimney placed over a lighted candle, figure 64. A strip of tin or

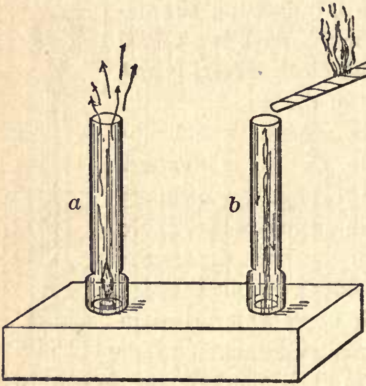


FIG. 63.

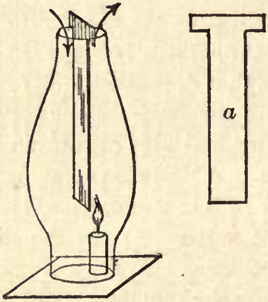


FIG. 64.

cardboard divides the chimney into two compartments. When the candle is arranged as represented in the figure, a current of air, as indicated by paper-smoke, passes down one side of the partition and up the other. The tin partition is sometimes suspended from a wire which extends across the top of the chimney.

No. 58. Apparatus to Show that Water and Air Are Poor Conductors of Heat.—This consists of a test-tube with a small thermometer in it. A thimbleful of ether may be poured upon the top of the water and set on fire; or, by holding the upper end of the tube against a flame, the water in the upper end may be boiled. In either case the thermometer indicates that the water in the lower part of the tube has not been heated so much as a single degree.

FIG. 65.

With air in the tube the upper end may be melted in the flame without affecting the thermometer in the lower part.

It is well to hold a piece of cardboard so as to shut off the radiation of heat from the flame to the lower end of the tube.

Cost of thermometer...................... 10 cents.

No. 59. Funnel for Hot Filtration.—The stem of a small glass funnel, by means of a short piece of rubber tubing, is made to fit water-tight inside of a "marbleized" iron funnel, figure 66.

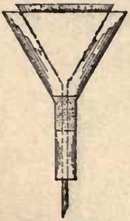


FIG. 66.

Hot water is put in the space between the two funnels, and a small flame is directed against the side of the outer funnel to keep the water hot.

Cost.—	Glass funnel, 2½ inches in diameter....	12 cents
	Iron funnel..........................	25 cents
		37 cents

No. 60. Illustration of Bunsen-Burner.—A short piece of small glass tubing is thrust into the end of the rubber gas-tubing of the laboratory, figure 67. Over the upper end of this glass tube a piece of paper is pasted, through which a number of pin-pricks are made to permit the gas to flow in several minute streams, the number of which depends upon several conditions, and must be determined by experiment. Over the upper end of this small glass tube a large glass tube, about four or five inches long and half an inch inside diameter, is held. Both of its ends are open normally, but the lower end may be closed by bringing it down upon a piece of cardboard, which fits upon the small glass tube.

FIG. 67.

The adjustment may be made so that an Argand lamp-chimney may be used for the outer tube.

Cost of glass tubing........................ 5 cents.

No. 61. Illustration of Blastlamp, Blowpipe, etc.—Two small glass tubes are bent at right angles and bound together by a short piece of rubber tubing, figure 68. Over the upper end of these a piece of glass tubing, four or five inches long and half an inch inside diameter, is held. The upper end is open, but the lower one is closed by bringing it down upon a piece of cardboard, which fits over the ends of the two small tubes. One of the small tubes

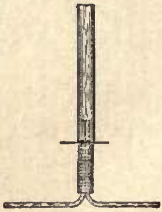


FIG. 68.

may be connected with one of the rubber gas-tubes in the laboratory, the other with the air-bellows.

Cost.. 8 cents.

No. 62. "Fish-tail" Burner.—A glass tube is bent at right angles in two places so as to lie in two planes at right angles to one another. One end is connected with the rubber gas-pipe, and the other end has an ordinary gas-tip attached to it by means of a short piece of rubber tubing, which is drawn over the end of the glass tube, and then the glass tube is thrust inside of the brass pillar.

FIG. 69.

It is very convenient for bending glass tubing.

Cost.—Brass pillar	....	2 cents
Lava tip	....	2 cents
Tubing	....	3 cents
		7 cents

No. 63. Tumbler Battery.—A large-sized electric-light carbon, half an inch in diameter by twelve inches long, is broken in two. One of these pieces is laid aside for another battery. A hole three-quarters of an inch deep is bored in the end of the other piece and the clean end of a copper wire is fastened in this hole by pouring around it melted lead or solder. A zinc rod, such as is used in the ordinary Leclanché cell, is bound to the carbon rod by

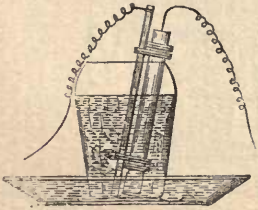


FIG. 70.

two rubber bands, and at the same time prevented from coming in contact with it by two rubber bands. These bands are cut from the end of a stout rubber hose.

Any one of the ordinary battery solutions is used (preferably one ounce of sodium bichromate, two ounces by volume of sulphuric acid, and seven ounces of water), and this is held in a tumbler which sets upon an ordinary porcelain plate. When the cell is not in use the zinc and carbon are lifted out of the solution, rinsed off, and laid upon the plate.

This single cell will furnish sufficient electricity to perform very many experiments.

Cost.—	Zinc..	8 cents
	Carbon..	4 cents
	Tumbler from apparatus No. 12.	
	Annunciator-wire, 3 ft........................	3 cents
		15 cents

No. 65. Plunge-Battery. — The plunge-battery is

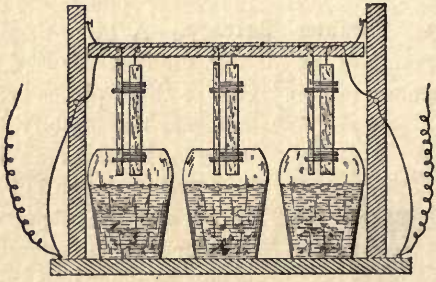


FIG. 71.

made by uniting from three to six of these cells and attaching the zincs and carbons to a strip of wood, so that all can be raised and lowered together conveniently, figure 71.

Three cells will decompose water rapidly, and will do all the work of such batteries as cost in the market $25.00.

Cost (about) .... 75 cents

No. 66. Telegraph Sounder.—Small iron wire is clipped into lengths of about three inches and tied with fine thread into a small bundle about one-quarter of an inch thick. Single-cotton-covered copper wire, No. 24, is carefully wound around this bundle in five layers. Liquid glue is used to prevent the wire from slipping off the ends of the bundle. The ends of the copper wire are attached to screws. One of these screws is in contact with a strip of ordinary tin (sheet iron coated with tin), which acts as armature and is its own spring. The strip of tin is three and one-half inches long and one inch wide. A cut about two-thirds the way across the strip is made at *a*, figure 73. The lower edge of the strip is folded upward along the first and second dotted line and flattened out with the hammer. The upper portion of the strip, now three times its original thickness, is bent outward at right angles to the plane of the paper, so that only the edge of it is seen in figure 72, while the small square of tin in the corner remains in the plane of the paper and is to be tacked to the board back of the apparatus. The electro-magnet is fastened to the board with glue and with wire loops. One wire from the battery is attached to one of the

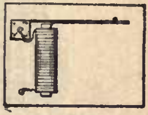


FIG. 72.

a

FIG. 73.

screws, and the circuit is made and broken by repeatedly touching the other battery-wire to the other screw. When the current passes, the tin is drawn against the end of the bundle; and when the current ceases to pass, the tin flies back against a nail which is driven into the back-board.

Cost.................................... 10 cents

No. 68. Apparatus for Decomposing Liquids by an Electric Current.—An 8-ounce wide-mouthed bottle is cut in two (page 9), and the neck portion is fitted into a block of wood, figure 74. A No. 7 rubber stopper with two holes fits in the neck. Two pieces of platinum wire (No. 24), each about two inches long, and connected to the ends of copper wire (No. 24), are fused into the ends of two short pieces of glass tubing, see figure 75. The glass tubes are thrust through the holes in the rubber stopper.

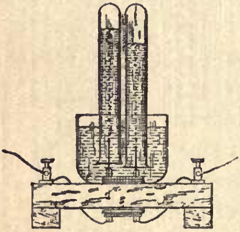


FIG. 74.

Over the ends of the platinum wires two test-tubes are inverted and are held in place by wire clamps, not shown in the figure. The copper wires are joined to binding-screws, with which the battery-wires are connected when the apparatus is in use. The bottle is so firmly fastened in the block that it cannot drop out and break the connecting wires when the apparatus is washed.

FIG. 75.

Cost.—8-oz. wide-mouthed bottle	....	6 cents
	4-in. platinum wire, No. 24	40 cents
	2 wood binding-screws	24 cents
	2 test-tubes from apparatus No. 48.	———
	Rubber stopper No. 7 from apparatus No. 49.	70 cents

No. 69. Electric Motor.—This consists of two rings, one larger than the other, figure 76, made of a number of turns of small iron wire. These rings are wound five layers deep with No. 24 single-cotton-coated copper wire, so that they may be magnetized by the electric current.

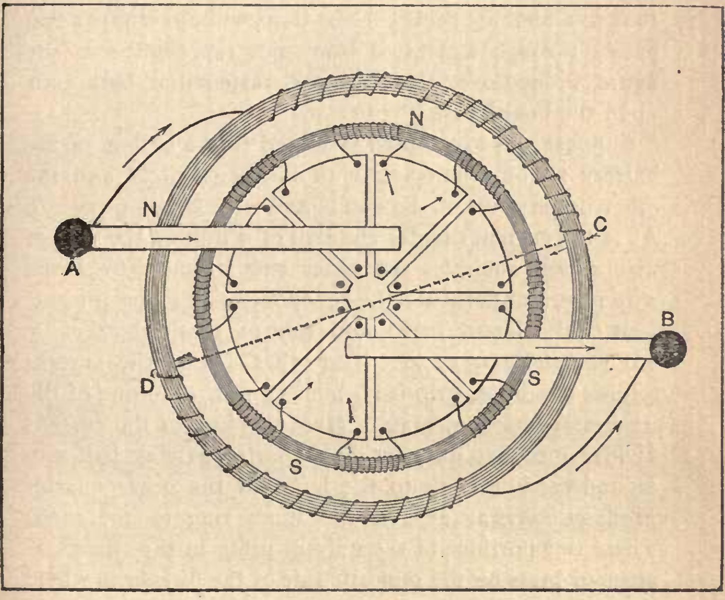


FIG. 76.

A few turns only of the copper wire are shown in the figure, in order that it may be possible to trace the path of the current. The outer ring is fastened to a board base and the inner one is fastened to a thin board disk, on the face of which are tacked triangular-shaped pieces of thin sheet-brass. Two strips of spring-brass are fastened to the binding-posts *A* and *B*, and are curved so that their ends only rub upon the triangular pieces of brass as the inner disk revolves. The axis of the revolving disk is a small wire nail, the lower end of which runs in a metallic socket in the base, while the upper end passes through a strip of brass, not represented in the figure, arched over the rings and fastened at both ends upon the board base.

Suppose the wire which is joined to the carbon of the battery to be connected with binding-post *A* and the other battery-wire to be connected with binding-post *B*. At *A* the current divides and half of it follows the copper wire which encircles the outer ring (from *C* to *D* the wire passes underneath the revolving disk along the surface of the board base), and returns to the battery by way of binding-post *B*. The other half of the current follows the brass strip from binding-post *A* to one of the triangular pieces of brass. Here this half of the current divides into two quarters, one quarter passing half-way around the inner ring to the left and the other quarter passing half-way around the inner ring to the right. These two portions of the current unite in the triangular piece of brass on the opposite side of the disk from where they separated, and pass along the second strip of brass to binding-post *B* and thence to the battery.

Cost.. 30 cents.

No. 70. Annunciator and Electric Bell.—Three small electro-magnets, *C*, *D*, and *E*, made as described on page 53, are fastened to a board, figure 77. Strips of tin, bent as described on page 53, are pivoted to the board, one near the end of each magnet. The free end of each of these strips of tin rests upon another cut in the shape of a long, slim triangle, and pivoted near its base to the board.

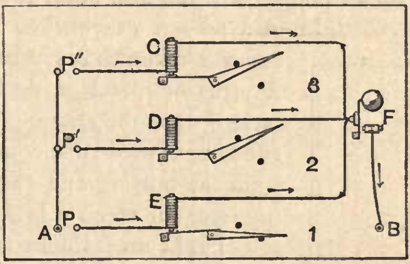


FIG. 77.

The broad end of each of these triangular-shaped pieces of tin is bent outward at right angles from the plane of the board. It is on this projection that each of the three strips first mentioned rests. The arrangement is such that when one of the triangular strips is pointing upward the weight of the other strip in contact with it will hold it in that position, but when once the triangular strip has fallen to the horizontal position the weight of its companion will not raise it again.

It will be readily seen by referring to the figure and supposing that the battery wires are in contact with the binding-screws *A* and *B*, that if we make connection between the two screws at *P* with a strip of metal representing a push-button, the current will pass around the magnet *E* and through the bell *F* and the lower pointer will fall and point toward No. 1, as represented in the figure; or, if we make connection at *P′*, the current will pass around the magnet *D* and through the bell *F*, and then the middle pointer will fall and point toward No. 2; or, if we make connection at *P″*, the current will pass around the magnet *C* and through the bell *F*, and then the upper pointer will fall and point toward No. 3.

No. 71. Burglar-Alarm.—A crayon-box with sliding cover is taken to represent a window. A strip of metal, *a*, *b*, figure 78, is tacked upon the cover. The ends of two copper wires, one coming directly from the battery and the other coming from an electric bell, which is in the circuit, are attached to the box, so that when the cover is raised the metal strip completes the circuit.

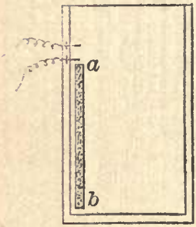


FIG. 78.

No. 72. Primary and Secondary Coils.—Small iron wire is tied into a bundle four and one-half inches long and half an inch thick, A, figure 79. A tube, four inches long and five-eighths of an inch in inside diameter, is made of several thicknesses of stout paper. Around this is wound four layers of annunciator wire, No. 18. The two ends project above, and are to be connected with the wires of the battery. This coil, which is called the primary coil, is designated by B in figure 79. Another paper tube, large enough to cover the primary coil, is made of stout paper, and around this is wound ten layers of single-cotton-covered copper wire, No. 30. Paper is wrapped around the coil between each layer. This

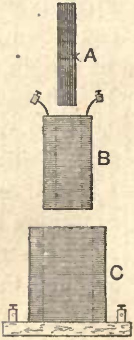


FIG. 79.

coil, which is called the secondary coil, is designated by the letter C in the figure. It is fastened to a board base, and the two ends of the small copper wire are fastened to binding-posts which are screwed into the base.

The primary current from the single tumbler-cell (No. 63) induces a current in the secondary coil of sufficient intensity to give vigorous shocks.

Cost.—Wire .... 40 cents.

No. 73. Telephone.—A telephone-magnet is mounted as shown in figure 80, upon one end of which are fastened two wooden button moulds about half an inch apart, and the space between them is wound full of single-cotton-covered copper wire, No. 36. The mouthpiece is made from wood three inches square, and a tintype two and a half inches square slides intoits position in grooves.

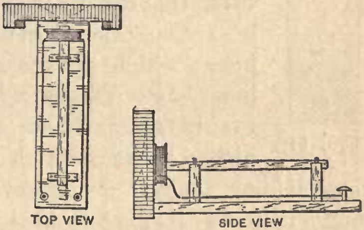


FIG. 80.

Cost.................................... 50 cents.

No. 75. Electroscope.—An 8-ounce glass flask with a rubber stopper, through which passes a copper wire curved into a loop at the upper end and having two strips of tissue-paper at the lower end, serves well for an electroscope.

No. 76. Electrophorus.—A large-sized jelly-cake tin with half a pound of sealing-wax melted in it so as to form a layer of uniform thickness is the electrophorus, and a smaller sized jelly-cake tin suspended by silk threads serves to convey the charge from it to the Leyden Jar, No. 77.

Cost.—2 jelly-cake tins	....	6 cents
½ lb. sealing-wax	....	10 cents
		16 cents

No. 77. Leyden Jar.—A tall beaker is coated both inside and outside with tin-foil stuck on by mucilage.

FIG. 81.

The coats cover the bottom and extend no more than two-thirds the way up the side. A flat cork fills the mouth of the beaker, and a wire, running through the cork, terminates in a loop above and a small brass chain below, which insures good contact with the inner coat. This jar when charged with about twenty sparks from the electrophorus furnishes a shock which may be felt by a large class joining hands. A beaker is used instead of a tumbler because its glass is a better insulator.

Cost.—Beaker (10-oz.).................... 22 cents

No. 79. Apparatus to Illustrate that Air or Some Medium is Necessary to Transmit Sound.—A glass rod is passed through one hole of the stopper of the receiver, apparatus No. 14, page 17. A small bell is attached to the lower end of this rod. The air is exhausted with the Franklin air-pump.

The bottle is sometimes filled with illuminating gas, hydrogen, or ether vapor, and their power to transmit sound noted.

Nos. 80 to 91.—Apparatus to Illustrate the Subject of Light.—Described fully in the author's "First Course in Science."

Cost of apparatus........................ $1.50.

PART IV. PHYSIOLOGICAL APPARATUS.

No. 92. Apparatus to Illustrate the Action of Muscles.—Two pieces of wood about half an inch thick, one inch wide, and nine and four inches long, respectively, are pivoted together by strips of tin on opposite sides, so as to represent a hinge-joint. Elastic bands are used to represent muscles. In figure 82, the apparatus represents the foot and leg, and the elastic band *a* represents the muscle in the calf of the leg. If we let the lower end of *c* rest upon the table, and press with the finger upon the upper end of *d*, we notice what a strong pull on the part of the elastic band is required to overcome a slight downward pressure by the finger. This suggests why the "tendon of Achilles" and the muscle in the calf of the leg need to be so powerful. The principle of the lever is suggested by this apparatus. It may be used to represent any hinge-joint in the body. A rubber band is attached to the opposite side of this joint to show how the muscles are arranged in pairs opposing each other. By adjusting the tension of these elastic bands so as hold the pieces of wood quite firmly in a straight line, we may show how the body is made rigid by contracting all the muscles which have anything to do with moving the joints.

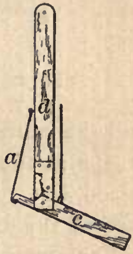


FIG. 82.

The action of the biceps muscle is illustrated by attaching a piece of wood, to represent the shoulder, figure 83. The rubber band *b*, which represents the biceps muscle, is attached below the elbow-joint and above the shoulder-joint. Two other rubber bands, *a* and *e*, are so adjusted that when all are hooked on the pieces of wood *c* and *d*, which represent the arm, hang down straight. If the rubber band *a*, which works in opposition to the biceps at the elbow-joint, is unhooked, the forearm *c* is raised as represented in figure 83. If this rubber band is hooked in place again and the rubber band *e*, which works in opposition to the biceps at the shoulder, is unhooked, the whole arm is raised, but remains straight. If both *a* and *e* are unhooked the arm is raised and bent over the shoulder.

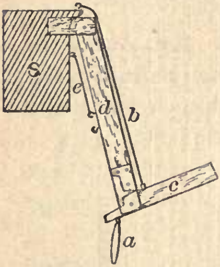


FIG. 83.

The apparatus is used, then, to illustrate the following six points:

1. How muscles work in opposition to each other over joints.

2. How a joint is made rigid by the contraction of muscles.

3. How we rise on the toe.

4. How we bend the forearm.

5. How we raise the arm when extended.

6. How we bend the arm over the shoulder.

No. 93. Apparatus to Show the Action of the Intercostal Muscles to Enlarge the Chest-Cavity.—Five slender sticks are pinned together as represented in figure 84. The cross-pieces represent ribs. Rubber bands, *cd* and *ef*, are attached diagonally between two of these strips of wood, as the intercostal muscles are attached to the ribs. A strip of cloth, stiffened with starch, is tied across between the lower ends of the two upright pieces of wood. This represents a section through the diaphragm. If we unhook the elastic band *ef*, the other, *cd*, contracts and raises the apparatus so that it takes the position represented in figure 84 B. If, on the

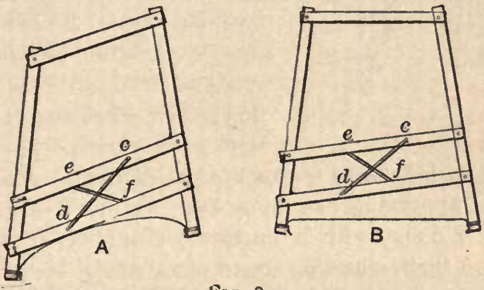
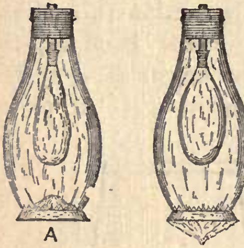


FIG. 84.

other hand, we unhook *cd*, the other elastic band, *ef*, contracts and gives the position represented in figure 84 A. The space enclosed within these sticks is evidently larger in figure B than in figure A. In the body, the diaphragm is a muscle, and, by relaxing and contracting, it moves more than the strip of cloth does in this apparatus.

No. 94. Apparatus to Show How Inhalation and Exhalation Result from the Expansion and Contraction of the Chest Cavity.—A common lamp-chimney is used to represent the chest-cavity. Rubber cloth is tied over the bottom to represent the diaphragm. A rubber stopper with one hole fits the top of the chimney, and through the hole a short piece of glass tubing passes, upon the lower end of which is tied a gold-beater's-skin bag (sometimes a rubber balloon is used instead) to represent the lungs. We may contract and enlarge the space inclosed within the lamp-chimney by pushing upward the rubber cloth or drawing it downward, when the bag which represents the lungs will collapse and inflate, as represented in figures 85 A and B.



A B

FIG. 85.

This apparatus has many uses, as the following will show: We may with a finger close the hole in the stopper, and then, when we try to move the rubber cloth up and down we appreciate how great is atmospheric pressure, somewhat as it is illustrated by Magdeburg hemispheres; but while we are doing this the bag inside of the chimney moves slightly, showing the relation of atmospheric tension to atmospheric pressure, as was illustrated in apparatus No. 25.

It may be used to introduce the study of the pump. Figure 86 illustrates the modification of the apparatus for this purpose. We enlarge the space in the chimney by pulling upward the rubber cloth, just as we enlarge the space in the cylinder of a pump by pulling up the piston, and the tension of the air in the chimney is now reduced, so that it no longer balances the atmospheric pressure. Atmospheric pressure then forces the water up the tube and into the chimney. If this tube is nearly closed at the upper end we have the fountain, caused by atmospheric pressure, as described under apparatus No. 29. If, now, we invert this apparatus and reverse the tube in the stopper, so that the large end of it may dip into water inside of the chimney, we may push upward the rubber cloth and have a fountain, caused by compressed air, as described under apparatus No. 29. This lamp-chimney is used in apparatus No. 33 and apparatus No. 34. It is frequently used for apparatus No. 37*a* by holding the chimney as shown in figure 86 and laying a book, with other weights, upon the top, then connecting a long rubber tube with a short piece of glass tubing, which passes through the stopper.

FIG. 86.

To illustrate how oxygen diffuses through the lungs into the blood, and how carbon dioxide passes out from the blood, carbon dioxide is passed into the chimney, either from apparatus No. 8 or directly from one's lungs, and then the gold-beater's-skin bag, which is an animal membrane like the lungs, is put back in place, as shown in figure 85. The short tube which carries the bag is made to extend only half-way up through the hole in the stopper, and another glass tube is thrust down into the same hole to meet the short piece of tubing. We then pull down the rubber cloth and draw air into the pseudo lungs. Osmose goes on between the gases in the chimney and those in the bag, as is shown by making the glass tube which leads out from the chimney dip into lime-water, pushing up the diaphragm and making this chimney exhale.

Cost.—Lamp-chimney and rubber cloth from apparatus No. 33.
Rubber stopper No. 7 with one hole (one hole plugged) from apparatus No. 49.
Gold-beater's-skin bag from apparatus No. 49.

No. 95. Apparatus to Illustrate the Circulation of the Blood and the Lymph.—A piece of rattan, figure 87, *a*, about one foot long is used to represent the capillaries of the human body. A syringe, *d*, represents the heart. A rubber tube, *b*, represents an artery, and another rubber tube, *c*, represents a vein. A short piece of rubber tubing, *e*, represents the thoracic duct. The tubes *e* and *c* are connected with the syringe by means of a glass Y-tube.

Water is used to represent the blood and the lymph. Every time the syringe-bulb is compressed, forcing more water into the rubber tube *b*, which represents an artery, a pulse may be felt by pressing the tube between the thumb and finger. If a cut is made in this tube the water spurts from it every time the bulb is pressed, illustrating how we bleed from an artery. The pores of the rattan offer considerable resistance to the flow of the liquid, and cause the artery to get somewhat distended, the elastic walls of which keep up a continual flow through the rattan (capillaries) between the heart-beats (compressions of the syringe-bulb), and hence there is a constant flow without pulse, through the rubber tube *c*, which represents a vein, and if it is cut, the flow of liquid is by a constant dripping. Some liquid under the pressure oozes out through the walls of the rattan, as it does through the blood capillaries in the body. This represents lymph, and the branch tube *e*, which enters the vein near the heart, when there is no outward but rather an inward pressure, carries into *o* circulation an amount of liquid equal to that lost through the walls of the rattan.

Various kinds of syringes may be used in the apparatus described above, but the one represented in figure 87 is made as follows: A short piece of rubber tubing, about one and one-half inches long, is drawn over a tapering wooden penholder, and with a sharp knife a short slit is

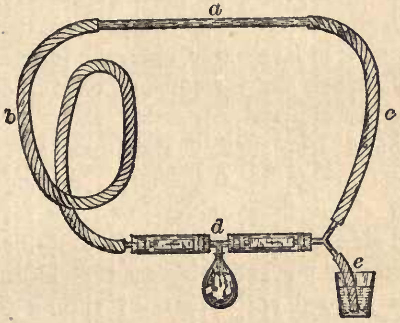


FIG. 87.

cut in one side of the tubing. One end of the tube is plugged with a short piece of glass rod, or even an end of the wooden penholder, about one-quarter of an inch long. This makes a very perfect valve. Liquids or gases forced into the tube will find exit through the slit, but cannot pass in through the slit since its sides shut together perfectly tight. One end of the Y-tube in the apparatus passes through a No. o rubber stopper, and one of these valves is then drawn over it. A piece of glass tubing, five-eighths of an inch inside diameter and three and one-half inches long, incloses this valve. In the other end of the glass tubing is another rubber stopper, No. 0, through which passes one end of a T-tube. The side branch of the T-tube enters a syringe-bulb and the remaining end passes through another rubber stopper into another piece of the large glass tubing, and another of the valves is drawn over it. A No. 0 rubber stopper fills the other end of this large glass tube, and through it passes a short piece of glass tubing connecting with the artery. The stoppers are tied in when much pressure is to be exerted upon the bulb. This is a powerful condenser, and is frequently used in connection with such pieces of apparatus as No. 29.

A convenient stop-cock is sometimes put into the rubber tube representing the artery. A piece of small glass tubing about three inches long has a small hole made in one side of it by the method described on page 14. The artery is cut and this glass tube inserted. The stop-cock is opened and closed by sliding the rubber tubing upon the glass tubing so as to cover or uncover the hole.

Cost.—	Rattan	5 cents
	Rubber tubes *b* and *c*, four feet and two feet	60 cents
	4 rubber stoppers, No. 0	12 cents
	T-tube	15 cents
	Y-tube	15 cents
	Rubber bulb	30 cents
	Rubber tubing for valves	3 cents
		$1.40

No. 96. Apparatus to Show how Muscular Action Assists the Circulation of the Blood in the Veins and the Flow of the Lymph in the Lymphatics.— The rubber tube *c* which represented a vein in the last piece of apparatus is used in this to connect the two chambers of the syringe-pump which contain the valves,

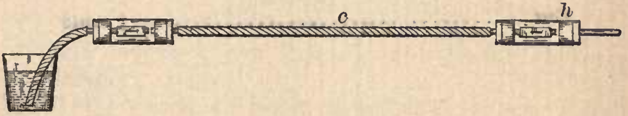


FIG. 88.

figure 88. A short piece of glass tubing, nearly closed at the outer end, is inserted in stopper *h*, and a short piece of rubber tubing at the other extremity of the apparatus dips into a tumbler containing water.

Water may be pumped through the apparatus by alternately pinching and releasing the rubber tube *c*. If both hands are used, water spurts ten or fifteen feet each time the tube *c* is compressed.

Thus the veins and lymphatics, which are intertwined among the muscles, are alternately pinched and released when the muscles contract and relax in exercise.

No. 97. Apparatus to Illustrate how the Tension of the Air in the Interior of the Ear is Adjusted to Changes of Atmospheric Pressure. — A 1-ounce wide-mouth bottle has a very small hole made in it by filing across the edge where the bottom and side meet. Over the top of the bottle is tied rubber cloth. When this bottle is put in the receiver, apparatus No. 24, and the air is exhausted or condensed, the rubber cloth is unaffected ; but where the hole in the small bottle is stopped with a little wax, the rubber cloth moves out and in as the air in the receiver is rarefied or condensed. The rubber cloth represents the tympanic membrane of the ear, and the small hole illustrates what is accomplished by the eustachian tube.

Cost.................................... 3 cents

LIST OF MATERIAL.

(The numbers in brackets refer to the catalogue of Messrs. Eimer & Amend, 205–211 Third Ave., New York City.)

1 lb. of glass tubing, $\frac{1}{8}$ to $\frac{3}{16}$ inch inside diameter (6540).
$\frac{1}{2}$ lb. " " " $\frac{5}{8}$ inch inside diameter (6540).
$\frac{1}{4}$ lb. " " rod, $\frac{3}{16}$ inch diameter (8004).
2 alcohol lamps, 4 oz. (6691*a*), or 2 Bunsen burners (5809).
1 quart of alcohol, or 5$\frac{1}{2}$ feet of rubber gas tubing, $\frac{1}{4}$ inch (8013).
1 triangular file, 4 in. (6282).
1 rubber bulb, 40 to 50 cc. (5767).
1 dropper bulb.
1 round file, 5 in. (6281).
6 test-tubes, 6x$\frac{3}{4}$ in. (8270).
Rubber stoppers (8010):
- 5 number 0 with one hole.
- 1 number 1 without holes.
- 2 number 1 with two holes.
- 1 number 3 with two holes.
- 1 number 5 without holes.
- 1 number 5 with two holes.
- 1 number 6 with two holes.
- 1 number 7 without holes.
- 1 number 7 with two holes.
- 1 number 7 with three holes.
- 1 number 9 with two holes.
- 1 number 10 with two holes.

7 ft. rubber tubing, $\frac{3}{16}$ inch inside diameter (8016).
1$\frac{1}{2}$ ft. rubber "pressure" tubing, $\frac{3}{16}$ inch inside diameter (8014).
Glass bottles, round, wide-mouthed (5676):
- 1 one-ounce.

4 eight-ounce (W. T. & Co. style).
2 thirty-two-ounce (E. & A. style).
Glass bottles, round, narrow-mouthed (5675):
1 one-ounce.
1 eight-ounce.
5 sixteen-ounce.
4 tumblers, large.
1 tumbler, small.
1 lamp-chimney, common.
3 lamp-chimneys, argand, small sized.
1 flask, 2 oz. (6342).
1 flask, 8 oz. (6342).
1 small glass dish.
6-inch square of wire gauze, 40 meshes to inch (8442).
1 ounce rubber cloth (8008).
1 lb. of mercury.
1 beaker, ten-ounce (5561).
2 T-tubes, $\frac{1}{8}$ inch (8358*a*).
1 Y-tube, $\frac{1}{8}$ inch (8358*b*).
1 goldbeater's skin bag.
1 small thermometer.
1 glass funnel, $2\frac{1}{2}$-inch (6388).
1 iron funnel.
1 brass pillar and lava gas-tip.
4 zinc rods for Leclanché battery cell.
2 electric-light carbons.
6 yards annunciator wire.
$\frac{1}{2}$ lb. copper wire, single cotton-coated, No. 24.
$\frac{1}{2}$ lb. copper wire, single cotton-coated, No. 30.
$\frac{1}{2}$ lb. copper wire, single cotton-coated, No. 36.
Small spool of iron wire, No. 16.
4 inches of platinum wire, No. 24.
1 telephone magnet, round.
2 binding posts, wood screw.
1 ft. of rattan, $\frac{1}{4}$ inch in diameter.
2 jelly-caketins, about eight and nine inches in diameter.
1 tin basin, about six inches in diameter.

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